Statyba

ISSN: 1392-1525 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcem19

MULTICRITERIA DECISION-MAKING SYSTEM FOR BUILDING REFURBISHMENT

E. Zavadskas , A. Kaklauskas & Z. Turskis

To cite this article: E. Zavadskas , A. Kaklauskas & Z. Turskis (1997) MULTICRITERIA DECISION-MAKING SYSTEM FOR BUILDING REFURBISHMENT, Statyba, 3:12, 62-68, DOI: 10.1080/13921525.1997.10531368

To link to this article: https://doi.org/10.1080/13921525.1997.10531368

Published online: 26 Jul 2012.

ISSN 1392-1525. STATYBA - CIVIL ENGINEERING - СТРОИТЕЛЬСТВО, 1997, Nr. 4(12)

MULTICRITERIA DECISION-MAKING SYSTEM FOR BUILDING REFURBISHMENT

E. Zavadskas, A. Kaklauskas, Z. Turskis

1. Introduction

This paper has been written with one concrete purpose in mind - to show how refurbishment process of buildings can be improved by using the alternative designing and multicriteria analysis methods suggested by the authors. These suggestions are presented in the analysis of the proposed Multicriteria decision-making (MDM) system for building refurbishment.

The assessment and selection of the best refurbishment version by means of traditional methods is performed on the base of one criterion or on a system of criteria, but without combining them up into one reduced index expressed in numerical form. Various limitations can also be applied in both cases.

In the first case, basing oneself on the criterion being analysed (mostly the cost), this index enables exact assessment of alternatives under comparison. However, in most cases the versions under investigation give a different degree of satisfaction to the interested parties. Besides, experts of the same branch, analysing the same alternatives, often assign them different utility degrees. So, apparently, a single criterion, even with diverse limitations in force, cannot give a full expression of goals pursued by various interested parties, possessed resources and environment. This creates additional difficulties on the way of making a right decision.

In the second case, when traditional methods are employed for alternative designing and selection of the most efficient refurbishment versions on the base of criteria systems characterizing them, large amount of information is used. Since in this case the indexes under investigation are not reduced in numerical form into one final criterion, the processing of a large amount of information makes it difficult to select the most efficient version.

These disadvantages can be avoided by using the methods of computer-aided alternative designing and multicriteria analysis.

This paper, further on, will bring some suggestions of how traditional methods of designing of the efficient refurbishment versions can be improved by using computer-aided methods of alternative designing and multicriteria analysis. In order not to repeat the materials of earlier publications, the analysis of the MDM System for Building Refurbishment contains references to books published earlier.

2. Definition of complex deterioration of a building

Refurbishment - construction activities with the purpose of essential rearrangement of existing building in order to eliminate its physical, economic, legal, architectural/aesthetic, functional, comfort, social and other kinds of deterioration, including maintenance imperfections and defects of engineering services.

Deterioration and obsolescence level of a building in dependence of various factors changes with the elapse of time (Fig 1):

1. Deterioration of a building: canopies, balconies, cornices and ledges, joints.
2. Inadequacy of building's thermal insulation as compared with demanded thermal requirements need for services (heating boilers and radiators, their controls), ventilation and water supply system.
4. Legal deterioration (measures intended for efficient maintenance of buildings: normative and technical base, organization and management structures, tenders for housing maintenance, etc).
5. Architectural and aesthetic obsolescence (from the point of view of fashion and image).
6. Functional obsolescence (arrangement of internal spaces).
7. Comfort-related deterioration (sound insulation, dampness conditions, draughts, temperature, lighting).
8. Maintenance-related deterioration (reduction of maintenance costs).
9. Social deterioration (compensations).
10. Obsolescence from the point of view of occupied location and surrounding buildings.

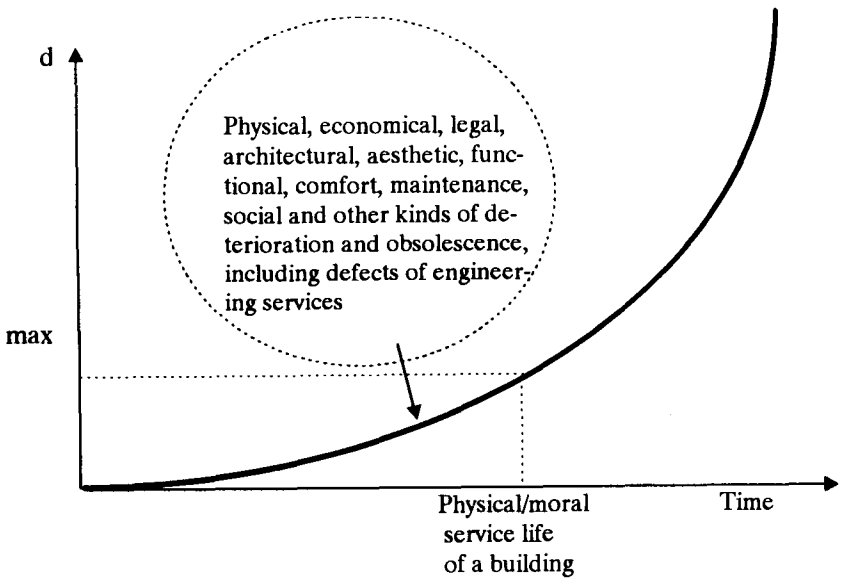

Fig 1. Progress of deterioration and obsolescence of a building and its service life

Legend:
d - deterioration and obsolescence level of a building
max - maximum deterioration and obsolescence level causing the necessity of refurbishment

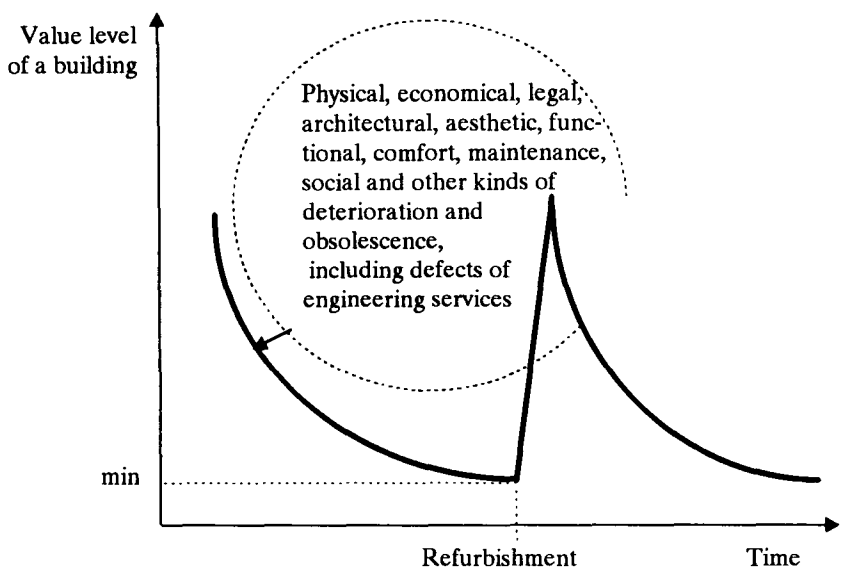

Fig 2. Value formation of a building

Legend:
min - minimum value level of a building

3. Selection for a rational building refurbishment version

The need for refurbishment of buildings can be looked upon as a difference between present and expected condition of a building.

3.1. Survey of present state (degree of deterioration) of a building

Present state (degree of deterioration) of a building can be determined by carrying out the following stages of survey:

- Pre-inspection stage (analysis of tenants' complaints about legal, architectural/aesthetic, functional, comfort, maintenance, social, obsolescence of the building and deterioration of its engineering services, etc).
- Survey of technical state of building elements (walls, windows, roof, floors).
- Survey of energy supply. At this stage, possibilities of effective use of electricity, gas, oil and solid fuel are investigated.
- Survey of technical state of engineering services (space heating, boiler, radiators, control methods), hot water, air filtration, humidification, lighting, building maintenance system, etc).

A list of main refurbishment reasons is made up and a sequence of actions and measures for the improvement of building's properties is set out during the survey.

3.2. Assessment of survey results

Having performed the survey of building's state of deterioration, an analysis is undertaken to find out whether elements and engineering services of the building are efficiently operated, or not. If not, it is necessary to estimate economic and energy effect that could be gained after the implementation of appropriate changes. Also, an analysis is performed of possibilities to use more effective fuel (running and capital costs) and to improve qualitative characteristics of the building.

3.3. Selection of a rational building refurbishment version

The refurbishment of buildings can be carried out by alternative materials, design solutions, equipment of engineering services and the like. The efficiency of a building under refurbishment changes in dependence of applied versions of these solutions. Alternative character of solutions allows for more rational and realistic assessment of economic, climatic, legal, social conditions and traditions; to cut down project costs; to achieve better satisfaction of architectural, comfort, functional, maintenance and other requirements of the client.

The selection of a rational refurbishment version for a building can be accomplished in the following ways. There can be minimum refurbishment - elimination of physical deterioration of a building (canopies, balconies, cornices and ledges, joints), maximum refurbishment (when all kinds of deterioration are eliminated) or one of intermediate versions between them (Fig 3). The selection of a refurbishment version principally depends on needs and existing financial capabilities of tenants. Now, in the

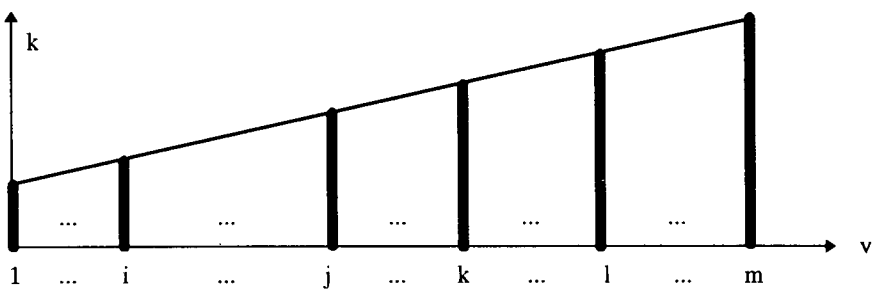

Fig 3. Analysis of possible refurbishment versions

Legend

v - building refurbishment versions

k - realization level of complex (total) refurbishment aims

1. Minimum deterioration caused refurbishment (canopies, balconies, cornices and ledges, joints) of a building

...

i. Partial thermal renovation of a building

...

j. Implementation of heating system's control and accountability

...

k. Legal provision (normative basis, organization and management structures, tenders for housing maintenance, etc.)

...

l. Complex thermal renovation of a building

...

m. Complex refurbishment of a building (elimination of all physical, economical, legal, architectural/aesthetic, functional, comfort, maintenance, social and other defects, including defects of engineering services)

present economic situation, the most realistic approach would be to carry out physical refurbishment in the first place and later on - thermal refurbishment with simultaneous introduction of heating system control and accounting. In course of these refurbishments, it is also necessary to strive for the improvement of architectural, aesthetic, comfort and other factors.

The rationality of refurbishment depends on specific needs and financial capability of tenants. For instance, a man suffering from asthma or allergic to fine dust will not wish to have such refurbishment version which would adversely affect his ailments. A poor man will principally seek for cheap version of physical and thermal refurbishment with simultaneous implementation of heating system control and accounting. A better-off tenant will go in for better architectural/aesthetic image, improved comfort, zoning of spaces and so on. So many people - so many goals and, consequently, so many possibly best refurbishment versions. In one aspect it may seem to be a "tendentious" choice, a "rule of thumb" decision. Although such assessment will be rather subjective, its result will give maximum satisfaction of tenants' goals and existing possibilities.

4. General scheme

In order to plan an efficient refurbishment of a building, it is necessary to carry out an exhaustive analysis of all its constituent parts. This problem is thoroughly looked into by numerous disciplines, for instance, architecture, building constructions, heating and ventilation, construction technology, economics and others. And MDM system for building refurbishment, striving for maximum efficiency increase of refurbishment projects, makes it possible to combine the tasks handled by all these disciplines into one whole. This system enables efficient performance of alternative planning, multicriteria assessment, utility degree determination and selection of most efficient versions of refurbishment projects and their constituent parts.

Project analysis is performed from goal-setting stage to the end of building maintenance. The main factors influencing the efficiency of a refurbishment project are given in Fig 4. First of all, the interested parties, aiming at an accurate assessment of these factors, work out a criteria system (refurbishment price, duration of realization, aesthetics and comfortability criteria, maintenance expenditures, satisfaction level of customers' demands, etc) describing them and determine values and significances of criteria. Depending on specific features of task being solved, a specified criteria system is used. Project efficiency can be described on the base on values and significances of criteria which, in their turn, depend on many factors. For instance, when analysing the same projects, their efficiency level by various customers can be assessed differently. This depends on numerous subjective and objective conditions: pursued goals, possessed money assets, acquired experience, valid laws, kind of property (state or private), etc. The more alternative versions are investigated before making final decision, the greater the possibility to achieve a more rational end result.

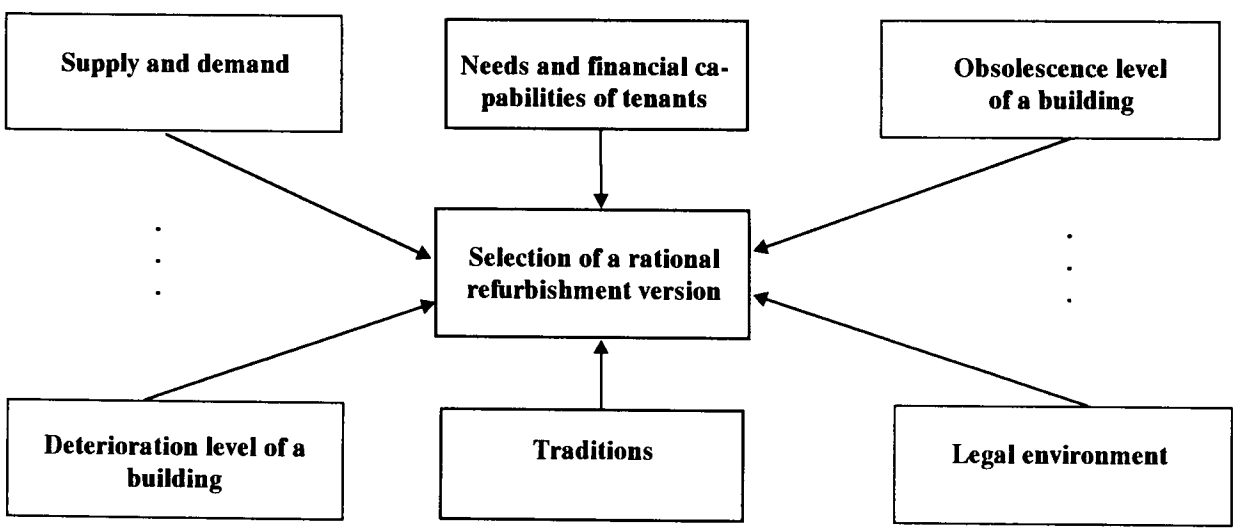

Fig 4. Effect of external environment on the selection of a rational refurbishment version

Further on, basing themselves on possessed information and the MDM system for building refurbishment, they perform multicriteria analysis of refurbishment projects components (walls, windows, roof, floors, engineering services, etc) and select the most efficient versions. After this, the received compatible and rational components of a refurbishment are joined up into projects. Having performed multicriteria analysis of projects made up in such a way, they select the most efficient ones. Strong and weak sides of the investigated projects are also given an analysis. Facts of why and by what degree one version is better than the other are also established. All this is based on indexes of projects under investigation, on values and significances of those criteria.

5. Multicriteria decision-making system for building refurbishment

The MDM system for building refurbishment is composed of two main parts: knowledge base and decision-making subsystem enabling to perform alternative designing and multicriteria analysis of refurbishment projects or their constituent parts.

5.1. The development of knowledge base

Having at first analysed various possible structures of knowledge base and modes of interaction between knowledge - bases separate parts, we have selected the most rational one consisting of the following integrated parts:

1) knowledge sheets for alternatives assessment, ie sheets containing information on systems of criteria describing projects (their constituent parts) as well as values and initial significances of these criteria.
2) knowledge sheets for alternative designing, ie sheets containing information on possible changing combinations of processes and solutions.
3) knowledge sheets containing graphical information characterizing the versions (plans, sections, front views of buildings and so forth);
4) recommendations on the filling-in of knowledge sheets.

Wider description of the above knowledge sheets is given in references 2 and 3.

The knowledge base contains quantitative, qualitative, graphical and other information fully characterizing the investigated alternatives and links between them. Quantitative information (project cost, cost of various solutions - walls, heating systems - maintenance costs, height and floor space of premises) can be exactly and objectively calculated or determined. Qualitative information (assessment of external aesthetic view, general comfortability and functional convenience of a building, etc) is in most cases determined by means of expert methods and is rather subjective.

In MDM system for building refurbishment, criteria systems, values and significances of criteria and other information characterizing the alternatives are determined prior to the beginning of calculations, ie a knowledge base is formed with a possibility of its further amendment. Quantitative parameters characterizing the versions are determined on the base of projects under investigation, analogues, recommendations, bills of quantities, normatives and other documents. Qualitative parameters, in most cases describing subjective and in numerical form not always with any accuracy measurable values, are determined by expert methods. Interconnections of investigated alternatives and their constituent parts are determined in the same way. On the base of this and other information, alternative versions are formed and the most efficient ones selected. Since the users often pursue different goals and possess different resources and capabilities, they can, in course of work or prior to it, amend or supplement the alternatives under investigation, the systems of criteria characterizing them, values and initial significances of criteria and other information. It can be asserted, therefore, that the efficiency of a MDM system for building refurbishment in large part depends on knowledge base and qualification of the system user.

5.2. Decision-making subsystem

The decision-making subsystem based on initial data supplied by the user and knowledge base (system of criteria, values of criteria, initial significances etc) forms decision-making and alternative designing matrixes and on their base performs alternative designing, multicriteria assessment, determination of utility degree and selection of the most efficient versions. In course of the alternative assessment process, the decision-making subsystem reduces all the analysed criteria into one. This enables exact assessment of versions, their positive and negative properties.

During calculation, the information directly connected with the problem under investigation is accu-

mulated in PC memory alongside with initial data. Thus, all the information fully describing the investigated alternatives is formed in the memory of a PC. Having analysed all this information and its mutual links and performed a number of operations, the decision-making subsystem of the MDM system for building refurbishment selects the most efficient version and gives out recommendations on its further improvement.

In our specific case, the decision-making subsystem is equipped with programmed formulas for the following methods:

- alternative projects and its constituent parts designing;
- significance determination of criteria;
- multicriteria analysis and utility degree determination of projects and its constituent parts;
- giving out of recommendations.

All the above methods suggested by the authors and programmed in the decision-making subsystem are described in different publications [1,2,3].

In order to check the correctness of the suggested MDM system for building refurbishment, the whole of its solution process has been more than once gone through manually. The results of manual and computer calculations matched. Besides, all separate working stages of the MDM system for building refurbishment as well as all complex calculations have been co-ordinated with experts in this field - ie the essence of the calculations has been found to be in conformity with their logical reasoning. Owing to suggestions of these experts, some useful changes have been introduced into the MDM system for building refurbishment. The check-up by the experts is bound with the fact that universal decision-making methods are not always suitable for specific tasks and can lead to gross errors or to bad results altogether.

MDM system for building refurbishment allows to determine weak and strong sides of each project and its constituent parts. Calculations are made to find out by what degree one version is better than others and reasons are disclosed why it is namely so. Landmarks are set for efficiency increase of project versions. All this is done argumentatively, based on indexes under investigation, on their values and significances.

Wider description of Multicriteria decision-making system is given in publications 2 and 3.

6. Conclusion

With the aid of MDM system for building refurbishment a considerable number of refurbishment problems can be solved:

- optimization of goals pursued by customers;
- formation of versions of refurbishment of buildings and their constituent parts;
- determination of factors having influence on the efficiency of refurbishment of buildings and its constituent parts and working out criteria system describing them;
- performance of project lifetime process optimization taking into account economic, maintenance, aesthetic, comfortability and other factors;
- preparation of recommendations on project development;
- the customers acquire better understanding of connections existing in refurbishment of a building between its constituent parts and making influence on its efficiency;
- MDM system for building refurbishment allows to determine weak and strong sides of each project and its constituent parts.

Reference

1. E. Zavadskas, F. Peldschus, A. Kaklauskas. Multiple Criteria Evaluation of Projects in Construction / Institute of Technological and Economic Development (ITED), Vilnius Technical University. V.: Technika. 1994. 226 p.
2. E. Zavadskas, O. Kaplinski, A. Kaklauskas, J. Brzezinski. Expert systems in construction industry. Trends, potential & applications / Vilnius Technical University. V.: Technika. 1995, 180 p.
3. E. Zavadskas, A. Kaklauskas. Pastatų sistemotechninis įvertinimas. Vilnius: Technika, 1996. 280 p.
4. E. Zavadskas, A. Kaklauskas, E. Bejder. Multiple Criteria Analysis of Projects. Aalborg: Aalborg Universitetscenter, 1992. 93 p.
5. E. Zavadskas, A. Kaklauskas. Automated Multivariant Design of Buildings, Multi-Purpose Comprehensive Evaluation and Selection of the Most Efficient Versions. Aalborg: Aalborg Universitetscenter, 1991. 66 p.

Įteikta 1997 11 27

PASTATŲ ATNAUJINIMO DAUGIAKRITERINĖ SPRENDIMŲ PRIĖMIMO SISTEMA

E. Zavadskas, A. Kaklauskas, Z. Turskis

Santrauka

Šiame straipsnyje pastatų atnaujinimas suprantamas kaip statybinė veikla, kurios tikslas pertvarkyti esamą statinį, siekiant pašalinti jo fizinį, ekonominį, inžinerinės

įrangos, teisinį, architektūrinį-estetinį, funkcinį, komfortinį, eksploatacinį, socialinį ir kitokį nusidėvėjimą. Į pastatų atnaujinimo poreikį galima žiūrėti kaip į skirtumą tarp esamos pastato padėties ir norimos.

Pastatų atnaujinimą galima atlikti naudojant alternatyvias medžiagas, konstrukcijas, inžinerinę įrangą, technologijas ir pan. Pagal naudojamų sprendimų variantus keičiasi atnaujinamo pastato efektyvumas. Sprendimų variantiškumas leidžia racionaliau ir realiau įvertinti ekonomines, klimato, teisines, socialines sąlygas, tradicijas; atpiginti projektą; geriau tenkinti architektūrinius, komfortinius, funkcinius, eksploatacinius ir kitus užsakovo poreikius. Atnaujinimas gali būti minimalus (dalinio fizinio pastato nusidėvėjimo (stogeliai, balkonai, karnizai, siūlės) pašalinimas), maksimalus (kai visi nusidėvėjimai pašalinami) arba kuris nors tarpinis variantas (dalinė ar kompleksinė šiluminė renovacija, šildymo sistemos reguliavimo ir apskaitos diegimas, racionalus normatyvų bazės paruošimas ir t.t.). Pastato atnaujinimo varianto parinkimas daugiausia priklauso nuo gyventojų poreikių ir esamų finansinių galimybių.

Siekiant nustatyti efektyvų atnaujinimo variantą, buvo sukurta pastatų atnaujinimo daugiakriterinė sprendimų priėmimų sistema, susidedanti iš žinių bazės ir sprendimų priėmimo posistemio. Žinių bazėje kaupiama įvairi informacija, sudaranti sąlygas sprendimų priėmimų posistemiui efektyviai atlikti pastatų atnaujinimo variantinį projektavimą bei daugiakriterinę analizę.

Žinių bazė susideda iš tokių dalių: pradinių duomenų žinių lentelių; atnaujinimo įvertinimo žinių lentelių, t.y. lentelių, kuriose pateikiama informacija apie alternatyvius atnaujinimo variantus (pastatų elementų, inžinerinės įrangos ir pan.); variantinio projektavimo žinių lentelių, t.y. lentelių, kuriose pateikiama informacija apie galimas alternatyvių atnaujinimo sprendimų tarpusavio derinių kombinacijas; grafinės dalies žinių lentelių, kuriose pateikiama grafinė atnaujinimo variantus apibūdinanti informacija; žinių lentelių užpildymo rekomendacijų.

Sprendimų priėmimo posistemyje yra užprogramuoti tokie autorių pasiūlyti metodai: projektų variantinio projektavimo; kriterijų reikšmingumo nustatymo; projektų sistemotechninės analizės; projektų naudingumo laipsnio ir sutartinės kainos nustatymo. Skaičiavimo metu kartu su pradiniais duomenimis ESM atmintyje iš žinių bazės kaupiama informacija, tiesiogiai susijusi su sprendžiama problema. Tokiu būdu ESM atmintyje suformuojama visa nagrinėjamas alternatyvas išsamiai apibūdinanti informacija. Išanalizavus visą šią informaciją ir jos tarpusavio ryšius bei atlikus daugelį veiksmų, sprendimų priėmimų posistemis suformuoja galimus pastatų atnaujinimo variantus. Po to šis posistemis, remdamasis užsakovo pateiktais pradiniais duomenimis (esamos finansinės galimybės, norimas atnaujinimo lygis ir pan.), išrenka efektyviausią alternatyvą.

Artūras KAKLAUSKAS. Doctor, Associate Professor. Department of Building Technology and Management. Vilnius Gediminas Technical University, 11 Saulėtekio Ave, 2040 Vilnius, Lithuania.

Graduate of Vilnius Civil Engineering Institute (since 1990 Vilnius Technical University (VTU)) in 1984 (civil engineer). Being involved into research on multiple criteria analysis of agricultural production buildings, he obtained PhD in 1990. Research visits to Aalborg University (Denmark) in 1991 and University of Glamorgan (UK) in 1993/1995. Author and co-author of 3 monographs and more than 50 papers. Research interests: theory of multiple criteria decision-making, expert systems, total quality management, computer-aided design.

Zenonas TURSKIS. Doctor. Department of Building Technology and Management. Vilnius Gediminas Technical University, 11 Saulėtekio Ave, 2040 Vilnius, Lithuania.

Graduate of Vilnius Civil Engineering Institute (since 1990 Vilnius Technical University) in 1979 (civil engineer). Being involved into research on multiple criteria analysis of dwelling houses he obtained PhD in 1993. Author and co-author more than 10 papers. Research interests: theory of multiple criteria decision-making, expert systems, total quality management, computer-aided design.